APPLICATION

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ON

# SYSTEM FOR, AND METHOD OF, IRRADIATING ARTICLES

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This invention relates to systems for, and methods of, irradiating products, including food products, to make them safe to use or eat. The invention particularly relates to systems for, and methods of, providing the irradiation within particular limits regardless of irregularities in the characteristics, including irregularities in the geometric shape, of the products including the food products.

## BACKGROUND OF A PREFERRED EMBODIMENT OF THE INVENTION

It has been known for some time that drugs and medical instruments and implements have to be irradiated so that they will not cause patients to become ill from harmful bacteria when they are applied to the patients. Systems have accordingly been provided for irradiating drugs and medical instruments and implements. The drugs and the medical instruments and implements have then been stored in sterilized packages until they have been ready to be used.

In recent years, it has been discovered that foods can carry harmful bacteria if they are not processed properly or, even if they are processed properly, that the foods can harbor and foster the proliferation of such harmful bacteria if they are not stored properly

or retained under proper environmental conditions such as temperature. Some of the harmful bacteria can even be deadly.

For example, harmful bacteria have been discovered in recent years in hamburgers prepared by one of the large hamburger chains. Such harmful bacteria have caused a number of purchasers of hamburgers at stores in the chain to become sick. As a result of this incident and several other similar incidents, it is now recommended that hamburgers should be cooked to a well done state rather than a medium rare or rare state. Similarly, harmful bacteria have been found to exist in many chickens that are sold to the public. As a result of a number of incidents which have recently occurred, it is now recommended that all chickens should be cooked until no blood is visible in the cooked chickens.

To prevent incidents such as discussed in the previous paragraphs from occurring, various industries have now started to irradiate foods before the goods are sold to the public. This is true, for example, of hamburgers and chickens. It is also true of fruits, particularly fruits which are imported into the United States from foreign countries.

In previous years, gamma rays have generally been the preferred medium for irradiating various articles. The gamma rays have been obtained from a suitable material such as cobalt and have been directed to the articles to be irradiated. The use of gamma rays has had certain disadvantages. One disadvantage is that irradiation by gamma rays is slow. Another disadvantage is that irradiation by gamma rays is not precise. This results in part from the fact that the strength of the source (e.g. cobalt) of the gamma rays decreases over a period of time and that the gamma rays cannot be directed in a sharp beam to the articles to be irradiated. This prevents all of the gamma rays from being useful in irradiating the articles.

In recent years, electron beams have been directed to articles to irradiate the articles. Electron beams have certain advantages over the use of gamma rays to irradiate articles. One advantage is that irradiation by electron beams is fast. For example, a hamburger patty having a square cross section can be instantaneously irradiated by a passage of an electron beam of a particular intensity through the hamburger patty. Another advantage is that irradiation by an electron beam is relatively precise because the strength of the electron beam remains substantially constant even when the electron beam continues to be generated over a long period of time.

X-rays have also been used to irradiate articles. The x-rays may be formed from electron beams. An advantage in irradiating articles with x-rays is that the articles can be relatively thick. For example, x-rays can irradiate articles which are thicker than the articles which are irradiated by electrons.

A problem has occurred in the past whether the irradiation has been provided by gamma rays, electrons or x-rays. This has occurred when the articles have had irregular characteristics such as irregular geometrical configurations. For example, a meat chub is generally circular in vertical section. This has caused the thickness of the chub to be different at every position in a vertical direction in the cylindrical shape of the chub. These differences in thickness have affected the radiation which the chubs have received at the different positions.

The radiation received at every position in an article should be within particular minimum and maximum limits. If the radiation received at any position within the article is below the particular minimum limit, harmful bacteria in the articles at that position may not be destroyed. If the radiation received at any position in the article is above the particular maximum limit, the quality or organoleptic characteristics of the article may be

negatively affected. It is difficult to maintain the radiation in the articles within the particular minimum and maximum limits when the article has irregularities in the characteristics at the different positions such as irregularities in the geometric configuration of the article. For example, a chub having a cylindrical configuration may be considered to have irregularities in characteristics because the vertical dimensions of the chub at the progressive positions of the chub in the horizontal radial direction are different. Irregularities in characteristics at different positions in an article may also result from irregularities in density at the different positions in the article.

Ethafoam and other equivalent materials have been disposed between the source of radiation and an article, particularly when the article is a drug or a medical instrument, to reduce the dosage applied to the article within particular minimum and maximum limits. However, the reduction in the radiation dosage of the article is not provided at different positions in the article in accordance with irregularities in the characteristics of the article at the different positions.

In co-pending application Serial No. 09/872,441 (SUREB-56121), filed by DENNIS G. OLSON for SYSTEM FOR, AND METHOD OF, IRRADIATING

ARTICLES and assigned of record to the assignee of record of this application, an article has irregular characteristics such as an irregular geometrical configuration. Radiation from a source is directed in a particular direction toward the article. The radiation energy from the source to the article at different positions in the article is absorbed in accordance with the irregularities in the characteristics of the article at the different positions to maintain the radiant energy at the different positions in the article within particular limits.

For irregularities of geometrical configuration in the article in Serial No. 09/872,441 (SUREB-56121), the absorption may be provided by a fixture having a geometrical configuration which constitutes the difference at every position between a substantially constant value and the geometrical configuration of the article at this position. The absorption is provided by conveying the article and the fixture past the radiation source in a direction substantially perpendicular to the direction of the radiation from the source.

## BRIEF DESCRIPTION OF A PREFERRED EMBODIMENT OF THE INVENTION

In a preferred embodiment of the invention, articles having irregular characteristics such as an irregular geometrical configuration or an irregular density are disposed in a

container which is moved in a first direction past a radiation source. Radiation from the source is directed toward the articles in the container in a second direction substantially perpendicular to the first direction. The radiation energy passing from the source to the articles at different positions in the articles is absorbed in accordance with the irregularities in the characteristics of the articles at the different positions to maintain the radiant energy at the different positions in the articles within particular limits.

For irregularities of a geometrical configuration or a density in the articles, the absorption may be provided by a fixture having a geometrical configuration or density which constitutes the difference at every position between a substantially constant value and the geometrical configuration of the articles at this position. The absorption may be provided during the movement of the container in the first direction with a fixture which has a geometric configuration or a density constituting the differences at every position between a substantially constant value and the respective one of the geometrical configuration or density of the articles at this position. The fixture is disposed externally relative to the container.

## BRIEF DESCRIPTION OF THE DRAWINGS

In the drawings:

Figure 1 is a simplified perspective view showing a system of the prior art for conveying an article past a source of radiation to irradiate the article;

Figure 2 is a simplified view illustrating how a system of the prior art irradiates an article such as a chub having a circular configuration in a vertical section;

Figure 3 is a simplified view indicating how a system of the prior art provides for an irradiation of an article such as a chub regardless of irregularities in the characteristics, such as irregularities in the geometrical configuration of the article, to provide for an irradiation of the article at the different positions in the article with a dosage within particular minimum and maximum limits;

Figure 4 is a simplified view showing how the apparatus of the prior art may include a fixture movable with the article past the radiation from the source to provide for an irradiation of the article at different positions of the article with an intensity within the particular minimum and maximum limits;

Figure 5 is a simplified view indicating a modification of the prior art fixture shown in Figure 4;

Figure 6 is a simplified view indicating a system in which articles having irregular characteristics are disposed in a container and in which a fixture external to the container is moved with the container past the radiation source to provide for articles within the container to be irradiated within the particular limits of maximum and minimum dosage at different positions in the articles; and

Figure 7 is a simplified view indicating a system including a modification of the fixture shown in Figure 6.

## DETAILED DESCRIPTION OF A PREFERRED EMBODIMENT OF THE INVENTION

Figure 1 is a simplified diagram of an irradiation system, generally indicated at 10, of the prior art for conveying an article past a source of radiation 12. For example, the conveyor system may be constructed as shown and described in patent 5,396,074 issued on March 7, 1995, and assigned of record to the assignee of record of this application. The conveyor system 10 includes a conveyor 14 for moving articles 16 past the radiation source 12 for irradiation of the articles by the source. The articles may be moved past the radiation source at a substantially constant speed within particular limits. The distance

between successive articles on the conveyor 14 may be maintained at a minimal value within particular limits. The articles 16 may be irradiated with gamma rays, electrons or x-rays or any other type of radiation without departing from the scope of the invention.

The articles 16 may have irregular characteristics at different positions. These irregular characteristics may include irregularities in geometrical configuration or in density or in a combination of irregularities in geometrical configuration and density. For example, the articles 12 may constitute chubs having a cylindrical shape. The radiation from the source may pass through each chub in a vertical direction corresponding to the circular cross section of the chub.

Figure 2 illustrates a plan view of the article 16 when the article is a chub. The chub moves in a direction 17 past the accelerator 12. The direction is perpendicular to the direction of the radiation from the accelerator 12. As will be seen, the irradiation provided at a position A in the chub 16 is different from the irradiation provided at a position B in the chub even though the positions A and B are at the same distance in Figure 2 from the accelerator 12 when the positions A and B are aligned with the accelerator. This results from the fact that the radiation has to pass through the chub 16

between the positions C and A on the one hand when the chub moves at positions C and A past the accelerator. On the other hand, the radiation has to pass only through the distances between D and B as the chub moves at the positions D and B past the accelerator.

The irradiation of the chub at the position A is accordingly different than the irradiation of the article at the position B. This may cause the chub to be under-radiated at some positions in the chub and to be over-radiated at other positions in the chub. Under radiating in the chub is undesirable because harmful bacteria in the chub are not killed. Over-radiating is undesirable because the quality or organoleptic characteristics of the chub may be negatively affected. It is accordingly desirable to radiate the chub within particular minimum and maximum limits. This causes harmful bacteria to be killed and the quality or organoleptic characteristics of the chub to be retained.

Opposite sides of the chub 14 may be irradiated by rotating the chub through 180° and then subjecting the chub to radiation a second time or by simultaneously irradiating the chub from opposite sides of the chub. However, irradiating the chub from opposite sides of the chub does not have any effect on the dissimilarities of the radiation at the

positions A and B. The reason is that the distance between E and A is the same as the distance between C and A and the distance between F and B is the same as the distance between D and B. As will be appreciated, the positions between C, A and E define a straight line and the positions between D, B and F also define a straight line. The direction between the positions C and E, and between the positions D and F, is substantially parallel to the direction of the radiation from the accelerator 12.

Although the discussion in the previous paragraphs has related to irregularities in the geometrical configuration of the articles, the discussion relates equally as well to irregularities in the density characteristics of the articles or the combination of irregularities in the geometrical configuration and in the density of the articles.

Co-pending application 09/710,730 (attorneys file SUREB-54214) filed in the U.S. Patent Office on 11/10/00 and assigned of record to the assignee of record of this application discloses and claims a member disposed between a radiation source and an article. The member absorbs the radiation from the source, when the radiation is above the preferred maximum limit, so that the radiation passing through the source to the

article will be within the preferred maximum and minimum limits in the article. However, the member is stationary.

The invention disclosed and claimed in application Serial No. 09/872,441 (Attorneys file SUREB-56121) assigned of record to the assignee of record of this application provides a simple but ingenious solution to the problems discussed above. In accordance with one embodiment shown in Figure 3, the article 14 is disposed in a fixture, generally indicated at 20, which may be a plastic or a metal such as aluminum, steel, plastic or other material having similar characteristics, in response to radiation from the accelerator 12, to those of the article 16. The geometrical configuration of the fixture 20 in a planar direction corresponding to the direction of the radiation from the accelerator 12 complements the geometrical configuration of the article 14 such that the combined or composite configuration of the fixture 20 and the article 14 is essentially a square in section. The article 14 does not have to be disposed snugly within the fixture 20. The fixture 20 is movable with the article 14 past the accelerator 12. It will be appreciated that the same principles discussed above apply equally as well to irregularities in the density of articles at different positions in the articles and to

irregularities constituting combinations in the irregularities in the geometrical configurations and densities in the articles.

In other words, the dimension of the composite of the article 14 and the fixture 20 in the direction of the radiation from the accelerator source 12 in application Serial No. 09/872,441(attorneys file SUREB-56121) is substantially the same at every position in the direction of the radiation from the accelerator 12 when the composite is moved on the conveyor past the radiation in a direction substantially perpendicular to the direction of the radiation from the source. In this way, the radiation dosage of the article 14 at the position B is the same within the maximum and minimum limits as the radiation dosage of the article at the position A. This is also true for every position along the line between B and A and at every position along the extension of this line between A and E.

The fixture 20 in application Serial No. 09/872,441 (Attorneys file SUREB-56121) has at the progressive positions characteristics constituting the difference between substantially constant characteristics and the characteristic of the article at the progressive positions. These characteristics may include a geometrical configurations or dimensions of the article at the progressive positions. The fixture 20 is disposed relative to the article

16 to provide the substantially constant characteristics for the combination of the article and the fixture at the progressive positions in the direction substantially perpendicular to the direction of the radiation from the accelerator 12. When there are irregularities in the geometric shape of the article, the fixture is disposed relative to the article to provide a substantially constant geometric shape for the combination of the article and the fixture at the progressive positions in the article. The same principles apply to irregularities in the density of the article as to irregularities in the geometrical configuration of the articles.

Thus, the radiant energy passing from the source 12 to the article 16 at the different positions in application Serial No. 09/872,441 (Attorneys File SUREB-56121) is absorbed in accordance with the irregularities of the article at the different positions so as to maintain the radiation dosage at the different positions in the article within the particular limits. Applicant's assignee provides for the deposition of the radiant dosage from the source within the particular limits at the different positions in the article regardless of the irregularities in the characteristics of the article at the different positions. As will be seen, applicant's assignee compensates for the irregularities in the characteristics of the article at the different positions in the article to provide a substantial

uniformity in the radiation dose at the different positions in the article within the particular limits.

In application Serial No. 09/872,441, (Attorneys File SUREB-56121) applicant's assignee also accomplishes the results specified in the previous paragraph (a) by providing a fixture having irregular characteristics such as an irregular geometric shape or density, at progressive positions to compensate for the differences in the irregularities of the characteristics, such as the irregularities in the geometric shape or density of the article, at the progressive positions and (b) by disposing the fixture relative to the article to provide the combination of the article and the fixture with the compensating characteristics at the progressive positions in response to the radiation.

The fixture 20 in application Serial No. 09/872,441 (attorneys file SUREB-56121) has characteristics of receiving at the progressive positions different amounts of radiation per unit of distance of travel of the radiation through the fixture. The different amounts of radiation per unit of distance for the fixture 20 correspond to the different amounts of the radiation per unit of distance for the article to maintain, within the particular limits at

the progressive positions, the radiation dosage received by the article per unit of travel of the radiation through the article.

Figure 4 illustrates a fixture, generally indicated at 22, which constitutes a modification of the fixture 20 shown in Figure 3. The fixture 22 may constitute fixtures 22a on one side of the article 14 in the direction of the radiation from the accelerator 12 and fixtures 22b on the other side of the article in the direction of the radiation from the accelerator.

When the irregularities on the opposite sides of the article 14 in co-pending application Serial No. 09/872,441 (attorneys file SUREB-561221) are symmetrical, the irregularities in the fixtures 22a and 22b are also preferably symmetrical. However, if the irregularities in the geometrical shape on the opposite sides of the article 16 are not symmetrical, the irregularities in the geometric shape of the fixtures 22a on the opposite sides of the article are correspondingly not symmetrical and the irregularities in the geometric shape of the fixtures 22b on the opposite sides of the article are correspondingly not similar. The same principles apply to irregularities in the density of the articles at the different positions in the articles.

As will be seen in Figure 4, the irregularities in the geometrical shape or density of the fixtures 22a and 22b in co-pending application Serial No. 09/872,441 (attorneys file SUREB-56121) extend into the irregularities of the geometrical shape or density of the article 14. The fixtures 22a and 22b are movable with the article 14 past the radiation from the accelerator 12, preferably in a direction substantially perpendicular to the direction of the radiation from the accelerator 12. This is indicated by an arrow 23.

In Figure 5, the fixtures 22 and 22b in co-pending application Serial No. 09/872,441 (attorneys file SUREB-56121) are combined to produce single fixtures 24a and 24b. The fixture 24a has irregularities in its geometrical shape or density corresponding to a combination of the irregularities in the fixtures 22a in Figure 4 at progressive positions substantially perpendicular to the direction of the radiation from the accelerator 12. In like manner, the fixture 24b has irregularities in its geometrical shape or density corresponding to a combination of irregularities in the fixture 22b in Figure 4 at progressive positions substantially perpendicular to the direction of the radiation from the accelerator 12. The fixtures 24a and 24b are movable with the article 14 past the accelerator 12. The fixtures 24a and 24b attenuate the radiation from the accelerator 12 in a manner similar to the combination of the attenuations provided by the fixtures 22a and

22b in Figure 4. The fixtures 24a and 24b extend into the irregular shape of the article 14.

In the embodiments shown in Figures 3-5, the fixtures (e.g. the fixtures 22a and 22b in Figure 4) extend into the space between the upper and lower boundaries of the article 15. For example, the upper areas of the fixtures 22a and 22b extend into the space below the top of the articles 16 in Figure 4. In like manner, the lower areas of the fixtures 22a and 22b in Figure 4 extend into the space above the portion of the articles 116 in Figure 4. This prevents the article 16 from being boxed. As will be appreciated, it is desirable to irradiate the articles 16 after they have been boxed. This is particularly true when a plurality of articles 16 are disposed in a single box or container.

Figure 6 illustrates an arrangement which constitutes a preferred embodiment of the invention and in which a plurality of articles 40 are disposed in a box or container 42. For example, the articles 40 may be chubs. Although the words "box" or "container" are used, the words are intended, individually and in combination in the claims, to indicate any type of housing for the articles. The articles 40 are preferably all of the same configuration although articles 40 of different configurations may be disposed in the same

box. Fixtures 44 are disposed above the top of the box or container 42 and fixtures 46 are disposed below the bottom of the box or container 42.

The fixtures 44 and 46 may have the same configuration when the articles 40 in the box or container 42 have the same configuration and when the irregularities at the upper end of the articles 40 are symmetrical with the irregularities at the lower ends of the articles. For example, the articles 40 in the box or container 42 may constitute chubs having a cylindrical configuration. When the upper ends of the articles 40 in the box or container 42 are not symmetrical with the lower ends of the articles, the fixtures 42 above the top of the box or container 42 may have a different configuration than the fixtures 44 below the lower end of the box or container 42.

As will be seen in Figure 6, the fixtures 44 and 46 can be considered, as a practical matter, to be inverted relative to the disposition of the fixture in Figures 3-6 so as to be disposed exteriorly of the box or container 42. This allows the fixtures 44 to be closely spaced relative to the top of the box or container 42 and the fixtures 46 to be closely spaced relative to the bottom of the box or container 42. The fixtures 44 and 46 may be

moved synchronously with the box or container 42 past a radiation source 50 corresponding to the radiation source 12 in Figures 3-5.

Figure 7 schematically illustrates another preferred embodiment of the invention. In this preferred embodiment, the articles 40 and the box or container 42 may be considered to be respectively equivalent to, or correspond to, the articles 40 and the box or container 42 in Figure 6. However, fixtures 52 in Figure 7 are different from the fixtures 44 and 46 in Figure 6. As will be seen, the fixtures 52 may be considered to be a composite of pairs of fixtures 44 and 46. Specifically, each of the fixtures 52 may be considered to be formed from an aligned pair of one of the fixtures 44 and one of the fixtures 46. The preferred embodiment shown in Figure 7 is accordingly advantageous because it reduces, by a factor of two (2), the number of fixtures shown in the preferred embodiment of Figure 6. The concept of the fixtures in Figure 7 corresponds to the concept of the fixtures 24a and 24b in Figure 6.

The embodiments shown in Figures 6 and 7 have certain advantages. They allow the articles 16 to be packaged and thereafter boxed before the articles are moved past the radiation source 50. This simplifies the logistics of moving the articles 40 past the

radiation source 50. Furthermore, since the articles 40 are boxed before the articles are irradiated, the articles do not have to be individually handled after they have been irradiated. This prevents the articles 40 from being subjected to harmful bacteria after they have been irradiated.

Although this invention has been disclosed and illustrated with reference to particular embodiments, the principles involved are susceptible for use in numerous other embodiments which will be apparent to persons of ordinary skill in the art. The invention is, therefore, to be limited only as indicated by the scope of the appended claims.